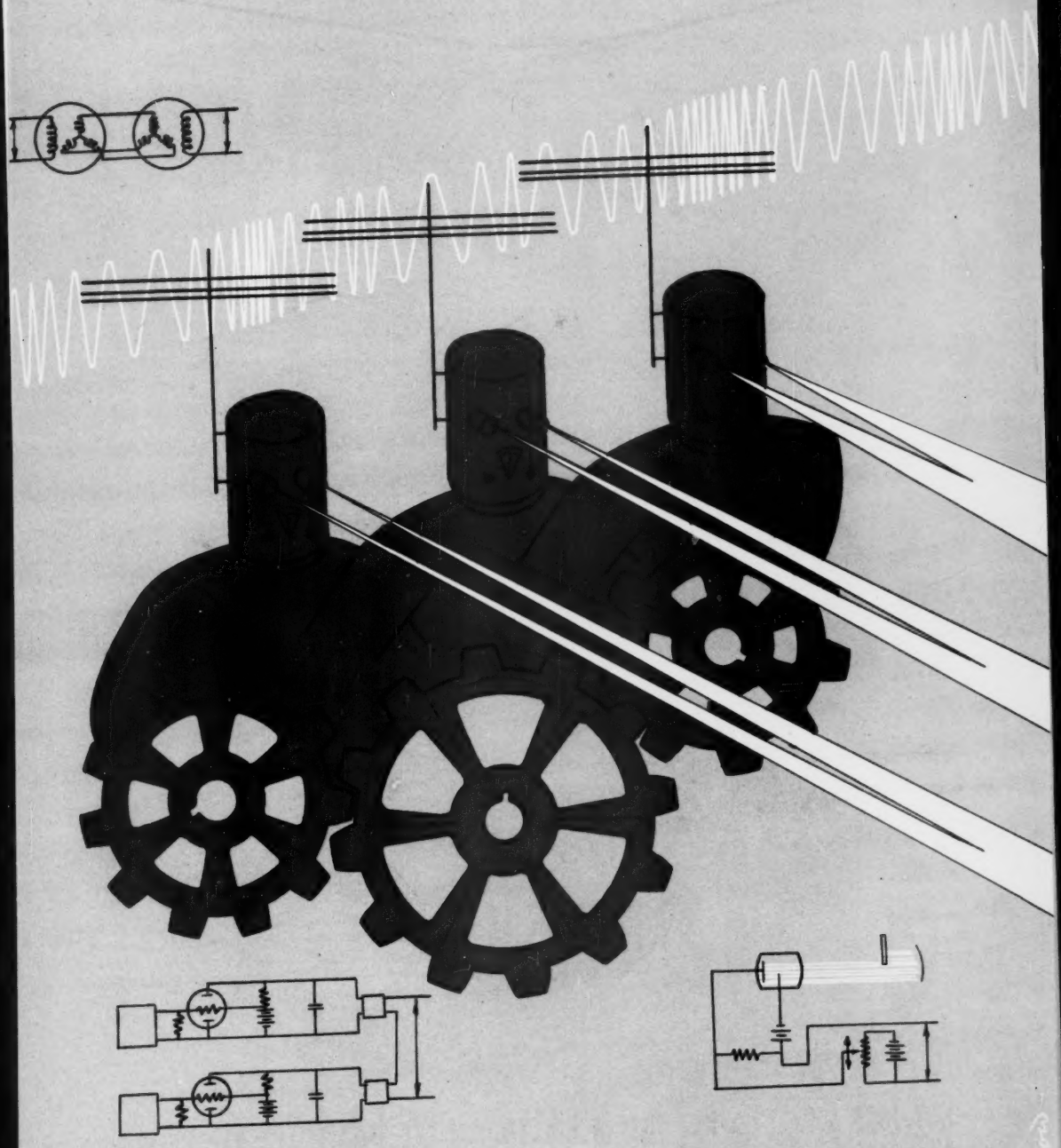
tech engineering news



january 1952

Another page for **YOUR BEARING NOTEBOOK**

How to keep a color press in the pink

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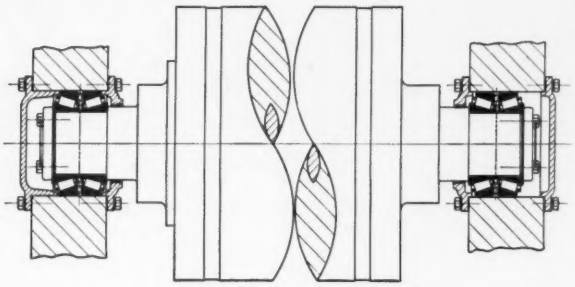
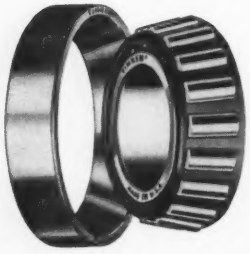
How to mount press cylinders

Type TNA Timken bearings are used at each end of this press cylinder. The bearing at the left is fixed by clamping the double cup while the other bearing is permitted to float. The bearing cones are clamped on the shaft by means of an end plate and cap screws which are locked by wiring the heads. The double cup for both bearings has a groove and oil holes through which the lubricant is supplied.





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Blast Furnace at Fairfield Steel Works
Photo by United States Steel Corporation

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nuclear powered aircraft

'Round the World Without Refueling

By Dr. M. C. Leverett

Aircraft Nuclear Propulsion Unit, General Electric Company, Oak Ridge, Tennessee

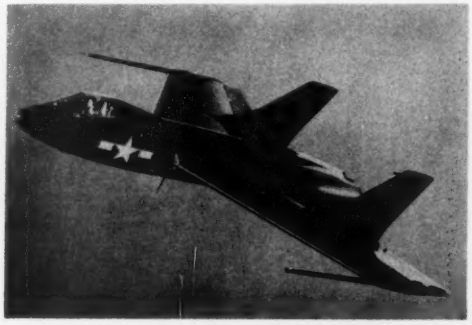
A discussion of the interesting subject of propulsion of aircraft by nuclear power is unfortunately considerably restricted by security. In spite of the restrictions, we can discuss in fairly free fashion the principles underlying nuclear powered flight, some possible methods of achieving it, and some problems which are involved. Before starting, however, we should pause a moment to answer the question, "Why do we want to fly an aircraft on nuclear power?"

Many years ago Breguet set down the formula which bears his name and which states that the range of an aircraft is proportional to its lift-to-drag ratio, to the efficiency with which its propulsive system works, and inversely proportional to the weight of fuel consumed per unit of work delivered to the propulsive system. Any decrease in the specific fuel consumption obviously leads to increased range. Because of the ingenuity of the designers of aircraft and engines the Breguet formula is scarcely of more than academic interest in these days. Devices such as accomplishing most of a flight slowly and using high speed only at critical times, refueling in flight, and discarding not only the fuel tanks but also the lifting surfaces which support them as soon as they are empty, all have been seriously proposed or practiced to increase the range of modern aircraft. However, it is no deprecation of our heavy bombers, to say that even more range would be desirable, particularly if it can be coupled with high speed. This is the point at which the nuclear propelled airplane comes into the picture. One pound of uranium-235 will produce heat on undergoing fission equivalent to the energy liberated by burning 1,700,000 pounds of gasoline. It is at once evident that if a means can be found for converting the energy of nuclear fission into thrust, an aircraft can fly for very long times on very small amounts of fuel. Indeed, fuel consumption would be measured not in thousands of pounds per hour, but in pounds per day. Because of the enormous amounts of energy available from a small amount of fuel, highly efficient utilization of this energy would no longer be crucially important. Thus, specific fuel consumption could be allowed to worsen somewhat if this were desirable in order to make some other feature of the power plant better.

Although the basic superiority of nuclear fuel over chemical fuel is superficially stated as a simple ratio of 1.7 million to 1, the implications and complications of this fact are extremely varied and far-reaching. For example, a nuclear aircraft could encircle the globe many times without stopping, although this particular maneuver would be more dramatic than useful. It could fly entirely around the world at local midnight, accomplishing the entire circuit in darkness and with the lower vulnerability which night flying confers. Careful husbanding of fuel, programming of flight speed and altitude, and closely timed flight plans would become unnecessary. Such an airplane could fly at its maximum speed and at any altitude over its operating range for all or any part of its mission and still be perfectly sure of having enough fuel to return to its home base by any route whatever. It is clear that many missions which are impossible for chemical aircraft would be possible with nuclear powered aircraft.

Energy of nuclear fission is usually manifested as heat. That is, a nuclear reactor is primarily a source of heat which must be converted into thrust or into mechanical work in more or less conventional ways. Hence, in any nuclear power plant, whether it is for an aircraft, a naval vessel, or for the generation of electricity on the ground, there will be a reactor and heat machinery. In the aircraft the heat machinery is the propulsion system. Secondarily, and somewhat unpleasantly, the reactor is a source of radioactivity; hence, there will also be a shield of some type or other.

There is scarcely a single type of aircraft propulsion machinery which has not been proposed for incorporation in a nuclear power plant. One obvious proposal is that propellers be used, driven by turbines which are in turn run by expanding vapor, such as steam or air, heated in the reactor. A variation of this scheme would be to extract the heat from the reactor by some liquid coolant and transfer it to the vapor or air in an external heat exchanger or boiler. Another fairly obvious proposal is that the reactor should directly or indirectly take the place of the combustion chambers of a conventional turbo-jet engine. Here again, the heat might be extracted from the reactor directly by the air or indirectly by other coolants, such as liquid metals, and transferred to the air outside the reactor. Obviously, the reactor might also take the place of the combustion apparatus in a ram-jet propulsion system. It has also been proposed that a compressor-jet type of propulsion system be used, with the compressor driven by vapor or hot air from the reactor and the heat supplied to the air by a heat exchanger through which the reactor coolant passes. In all cases, except that of the ram-jet and other direct air cycles, it is required that heat be transported in a coolant from the reactor to the propulsion machinery. In making a choice among the various types of propulsion machinery which have been suggested, the designer must perform detailed and careful analyses of many different possible combinations. For example, if a propeller type pro-

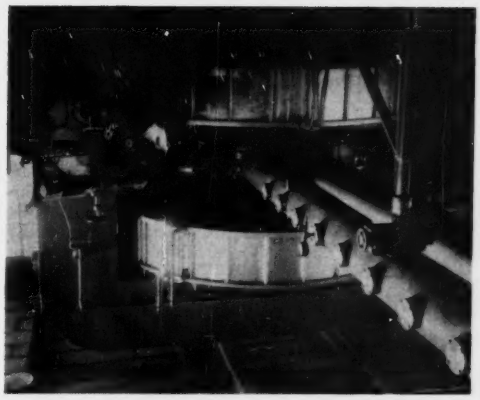


pulsion system is chosen, the hot fluid from the reactor must be piped to the turbines which drive the propellers; these in turn must be mounted on the wings. Thus each propeller must be provided with its own reactor, or hot fluids must be piped around the airplane from a central reactor heat source. Any reactor coolant will undoubtedly become somewhat radioactive in passing through the reactor, and this alternative hence is not attractive. On the other hand, providing each propeller with its own reactor is not easy for two reasons. First, the weight of a reactor, with its shield, is very large; more than one reactor and shield therefore is highly undesirable. Second, two reactors per airplane would require more than twice the fuel investment.

Although the design of the reactor will be greatly influenced by the coolant chosen, the basic principle upon which the reactor operates is as follows: the reactor may be thought of as a more or less cylindrical body throughout which a fissionable material such as uranium-235 or plutonium-239 is distributed. The reactor also contains passages for the flow of the coolant through it and also a material which is called a *moderator*. The reaction starts with the capture of a neutron by a nucleus of, say, uranium-235. Since neutrons are present in small concentration in the atmosphere everywhere, this serves to start the reaction. Immediately after capture of the neutron, the U-235 nucleus disintegrates with the liberation of two to three neutrons and two atomic nuclei (fission fragments), both smaller than the original nucleus. Most of the energy of fission is carried off by the fission fragments; this energy is imported to the material into which they are cast and appears as heat. Gamma rays and beta rays also are given off in the fission process.

The two to three neutrons given off are ejected into the body of the reactor and may undergo one of three different fates. (1) They may escape from the reactor entirely and be captured outside it by some parasitic nucleus in the structure of the shield or its surroundings. (2) They may be captured by some of the non-fissionable materials in the reactor itself. (3) They may be captured in another U-235 nucleus, following which additional neutrons will be given off. If we can design the reactor so that as many as about 40 per cent of the neutrons given off in fission are captured in other fissionable nuclei in such a way as to cause fission there, the reaction will continue indefinitely until the fissionable nuclei are used up.

The basic problem of reactor design is to reduce to acceptably low values the first two methods of loss of neutrons mentioned above; that is, leakage from and parasitic capture in the reactor. Leakage may be counteracted to some extent by surrounding the reactor with a neutron reflecting material, which scatters but does not capture the neutrons. For example, graphite and beryllium oxide are known to be good reflectors. Excessive capture of neutrons in non-fissioning nuclei in the reactor may be avoided by eliminating from the reactor atomic species which have a strong tendency to capture neutrons. Unfortunately, some of the materials which are most suitable for use as reactor structure, and without which the reactor will not support itself, have rather high capture cross sections. These are thus poisons for the nuclear chain reaction, although essential for the mechanical stability of the reactor. Obviously, we may increase the fraction of the neutrons which are absorbed in U-235 nuclei by increasing the proportion of U-235 present in the reactor. Unfortunately, this increases the amount of fissionable material invested in the reactor. We usually, therefore, resort to the device of introducing into the reactor a



Basic research conducted on nuclear reactions.

moderator. A *moderator* is an element of low atomic weight and low capture cross section for neutrons. Because of its low atomic weight a neutron striking it loses a relatively large fraction of its energy in each such collision. Because of its low capture cross section, it does not capture many of the neutrons which strike it. After the neutrons are thus slowed down or moderated, their capture by the fissionable material in the reactor becomes much more probable since the cross section for capture of low energy neutrons is higher than that for high energy neutrons. Typical moderators are graphite, ordinary water, heavy water, beryllium and beryllium oxide. The control of the chain reaction is in principle exceedingly simple. One of the most direct means of control is to arrange an absorbing rod so that it can be inserted into the reactor or withdrawn from it. If the rod is withdrawn from the reactor, it will absorb a smaller number of neutrons than before. If, in its original position, the rod was absorbing that number of neutrons which made the reactor just critical (that is, neither rising nor falling in power), then withdrawal of the rods will create a slight excess of neutrons in the reactor and the power will begin to increase. If, for example, we withdraw the rod so that the fraction of the neutrons absorbed in fission is 0.1 per cent greater than before, then the number of neutrons in the reactor will increase by 0.1 per cent in each neutron generation. Since the neutron generation time is extremely short, the reactor will build up rapidly in power in an exponential manner. When it is desired to stop this build up, all that is necessary is to insert the control rod to its original position. This will deprive the neutron cycle of its 0.1 per cent excess and the power of the reactor will stay steady at the new level thus reached. Other methods of control have been proposed also. For example, in a reactor which has a reflector, removal of part of the reflector will allow the leakage of more neutrons than before. This will decrease the reactivity and constitutes a method of control. Also, removal of part of the moderator or of some of the fuel itself from the reactor will decrease the reactivity, and these expedients may also be used as control mechanisms.

It is evident that the control of the reactor is an important matter; not so much because of the remote possibility that the reactor might turn itself into a low grade atomic bomb, but because if the power of the reactor fluctuates without a corresponding fluctuation

(*Continued on page 14*)

some elective courses

E43a, b; E44a, b reading seminar

E43a, b and E44a, b would be the catalogue numbers of the reading seminars created by Ted Wood if they were listed in the catalogue, which they aren't. This is probably attributable to the desire of the instructor, Wood, to keep the seminars fairly exclusive, and usually only those who know someone already enrolled in the seminars ever hear of them. No doubt this briefing of them in *T. E. N.* will not greatly alter that situation.

As the seminars never number more than eight or ten, one is compelled to get to know Wood personally, a very rare condition at M. I. T. The seminars meet one hour per week at the convenience of the class; since there are so many of them, one is able to fit one to his schedule with no trouble at all. Two years of these weekly meetings are credited by the Institute as being equivalent to the regular E43 and E44 courses.

To those who are interested in increasing their knowledge of literature in a logical, orderly fashion, this course is not offered. Above all, it is not offered for those whose interest in literature goes no further than the satisfaction of the senior year humanity requirements. This eliminates about eighty-five per cent of the student body.

Those who believe that by reading they can widen their human experience (vicariously, to be sure), increase their insight into human nature, and learn to understand themselves and others; those who are interested in discovering non-technical values in life; those who feel something very vital to a full life is found in literature; these are the ones whom Wood wants in his seminars.

To achieve his ends, Wood selects mostly contemporary works which reflect the problems of the individual and the group in our modern society and propose possible solutions to them. Consequently his seminars awaken many to very realistic facts of life overlooked by other classrooms around Tech.

R. P. Donovan, '52

15.30 personnel administration

How do you get the most effective results out of people? This is an indispensable question for every man who works with other people. It is the question which 15.30 attempts to answer.

Professor Pigors and Professor Eberly teach Personnel Administration as "a point of view and a method." The point of view is valuable to every Tech student regardless of course. The method, while applicable to innumerable situations in life, is probably most important to those men who plan to work in industry after graduation.

A "3—6" course, 15.30 is somewhat overrated as to hours. The text is an excellent one and is a combination text- and casebook. The lectures are important and note taking is advisable in view of four-hour quizzes and a two-hour final exam. There are usually three or four cases which must be written up and handed in. Each is short enough to be written in an evening. There is no outside reading requirement.

Personnel Administration is often confused with 14.60, Labor Relations. While it is true that the two courses overlap in certain areas, there are basic differences. Essentially, 14.60 deals with union-management relations, 15.30 being more concerned with personnel problems which are not necessarily union disputes.

This course is not a difficult one for most students. However, it is a very valuable one in that it provides a complete, well organized picture of the basic principles of personnel administration and its place in industry and in everyday life.

Jesse E. Erickson, '53

8.09 techniques of experimental physics

Most Techmen have felt the urge at one time or another to blow glass into various shapes or to turn out gimmicks on a lathe. Experimental Physics Techniques Lab is one place where they can satisfy this urge.

The purpose of the lab is to acquaint the student with some of the general procedures in experimentation. Some of the class time is devoted to direct practice of various manual techniques; nine hours, for example, are spent in the glass blowing laboratory, and another nine in the machine shop working with a lathe. Some practice is also provided in microsoldering and high vacuum technique. There are no formal reports required for such practice sessions; the grade is based on the quality of the finished product that the student turns out.

However, about one third of the class periods are devoted to more formal projects which are faintly reminiscent of 8.01 labs. The experiments themselves are rather boring, but require no great thought or effort (a typical one: measuring the temperature of a small furnace by means of an optical pyrometer). The reports do not have to be great works of art, but they require about four hours' preparation. All in all, these formal experiments are mildly distasteful but endurable.

The method of teaching in 8.09 is one of the course's biggest assets. Most of the instructors are very informal and friendly. They really advise rather than instruct. Time is seldom critical; none of the projects requiring the use of some new technique are due until the end of the term, and the lab is always open for those who need extra practice. As a whole, the course provides some valuable experience in basic experimental operations.

J. S. Mathis, '53

M62 modern algebra

Modern Algebra is intended primarily for undergraduate mathematics students, but the topics covered are so varied that others often take the course either to learn some of the methods of rigorous mathematics or to learn more about some special subject which interests them. The prerequisite listed in the catalogue is M22. However, since M62 does not depend upon concepts introduced in other courses but rather develops its own, it can be taken any time that the student feels he is capable of handling the rigorous approach to mathematics. It is generally offered both terms since the demand is so great, and has been scheduled at two o'clock on Monday, Wednesday, and Friday for the Spring Term, 1952.

The course begins with integral domains and fields, which are basic concepts of almost all mathematics. The concept of the field, which is the more useful of the two, is covered all too hastily. Number theory and

(*Continued on page 18*)

flight without power

The Methods and Development of Glider Flight

By Raymond G. D'Arcy, '54

The early history of attempts at heavier-than-air flight extends into the dim regions of antiquity. Egyptian ideographs, Greek legends, and the efforts of medieval scholars such as Leonardo da Vinci, show that men have long recognized the possibility of human flight. There were many instances of foolhardy experimenters who jumped from towers while flapping a pair of homemade wings, but these trials usually ended disastrously, and there are no authentic records of successful flight before the nineteenth century.

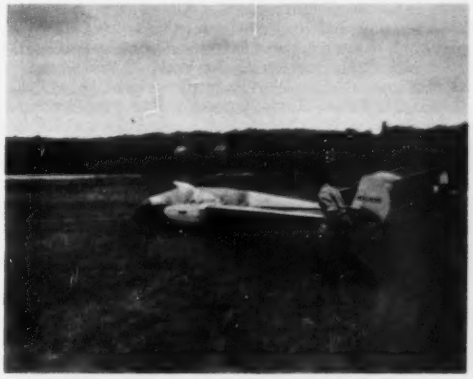
At the beginning of the nineteenth century, Sir George Cayley began to study the principles of flight mathematically, but turned later to lighter-than-air flight without attempting glider construction. There were several other French and English scientists who made contributions to flight theory, but little experimenting was done until 1855, when a French sea captain, LeBris, built a machine designed after the albatross which could be towed with a man into the air, kite fashion.

The cause of heavier-than-air flight languished until a German, Otto Lilienthal, combined theory and practice and in 1891 built the first properly designed gliders which would carry a man in free flight. Lilienthal's gliders, which supported the pilot by the arms in an upright position with his feet dangling, were launched by running downhill, and were controlled by the acrobatic weight shifting of the pilot. Although Lilienthal made flights of over nine hundred feet, he did not manage to perfect a system of control, and died in a crash in 1896. His accomplishments were widely publicized, and aroused both public interest and active experimenting, especially in America, which next took the leading role in aircraft development.

Octave Chanute, an American civil engineer, began to design and build gliders in 1896. After experimenting with Lilienthal type gliders and a plane of his own with twelve movable wings, Chanute finally designed a glider having two pairs of cambered wings, trussed one above the other with vertical struts and wire, a vertical rudder, and a light but rugged frame which served as a model for our first powered biplanes. However, control of this plane still entailed some shifting of the pilot's weight, and the best distances were under a thousand feet.

A dual utility glider floats in for a landing.

Next, the Wright brothers, in 1900, began experimenting with gliders, with the aim of perfecting stability and controls. By placing the pilot in a prone position and using landing skids on a Chanute type biplane, they reduced air resistance and facilitated launching. Then, by using a movable elevator in front of the wing and by making the vertical tail movable they were able to control the steepness of their glide, and by introducing a wing warping mechanism they were able to control lateral stability and to bank into partial turns. After testing and improving their designs by flights in 1902, they were satisfied that they had reached sufficient stability and control in their gliders, and they began work on a powered plane. With the success of their first powered flight on December 17, 1903, the Wrights abandoned gliding for a long time.



A modern high performance sailplane being launched by winch.

Meanwhile, another American, a Professor Montgomery of California, who had been working in obscurity on glider theory since 1883 and who had begun flights in 1900 without attracting much attention, burst into the limelight in 1905 when he began to give exhibitions of launching gliders from balloons at four thousand feet. However, these eshibitions were terminated with the death of one of his pilots in an exhibition flight. Montgomery's earlier work had much theoretical value but did not greatly affect aircraft development because, intended or not, much of his work was carried on in secrecy.

After the development of powered aircraft, gliding was for a while much neglected. The only noteworthy occurrences before the World War were a few French duration flights of five and six minutes, and Orville Wright's ten minute soaring record set in 1911 in the course of testing a new stabilizer at Kitty Hawk.

Now perhaps a brief survey of basic aeronautical

(*Continued on page 20*)

machine replaces man

The Servomechanism in Industry

By Peter Embree, '55

The robot, the slave, so necessary for the humanitarian philosophers' Utopia, is on his way. "He," however, does not take the human form, and is not referred to as "he" but as "it." A particularly expensive, erratic or exotic one, might be referred to as "she."

Robots come in all sizes, shapes, and forms. Their coming has been quiet and unobtrusive. Mutations have been high in successive generations. Some are capable of limited learning powers; some work alone; some can only work in groups. They are hardly laboratory curiosities, but vital factors in American production, standard of living, and military strength.

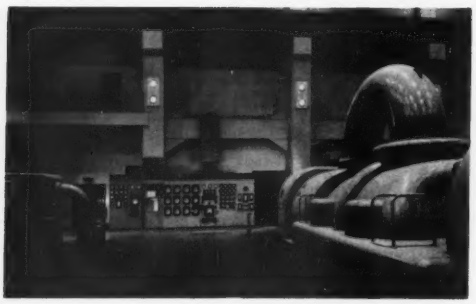
Man has been fairly successful at getting machines to do his physical work for him. He is now working on the job of creating machines to do his more complicated and difficult thinking for him. Thus we have calculating machines and the garden variety of adding machines to do our computations; we have mechanisms that point our guns for us and run our factories. In short, we have machines that can make and effect some of our more time consuming decisions for us.

Speak to the everyday man of robots, or servomechanisms, and he won't know what you're talking about; mention automatic controls to him, and he will understand you immediately. "Like the thermostat in my house," he'll say, "or the thing that keeps the water closet full without running over." Or he might mention something that he has observed at his work, especially if he is employed in a process industry. For it is in the process industries that automatic controls find their widest application and have the greatest economic significance.

Oddly enough, although automatic controls have been in use ever since there were governors on steam engines, accountants and accounting problems probably had a great deal to do with the new field of instrument control as it exists today.

Industries are run by business men seeking profits, and the process industries are no exceptions. Accountants trying to break down the costs of manufacture with an eye to cutting down waste and keeping track of expensive raw materials found and installed instruments that could measure and record quantities of power and materials at points of use. Since instruments already controlled pens on charts, it was but a short step to the point where someone suggested that instead of watching the meters and adjusting the process manually, why not just find a way to have the instrument control the valve or switch or whatever it is that needs to be changed, thus eliminating the need for continually watching the meter and also allowing a continuous automatic control of the process.

Los Angeles Harbor steam plant controlled from central panel.



Thus it came to be that the existing industries of the 1930's were instrumented. The problems involved in applying instrumentation to these existing industries were many. Such problems as choosing which particular product qualities to control and finding the best methods for controlling them with existing equipment often led to relatively complicated and expensive equipment without too great a degree of accuracy, and the completely automatic factory was still an instrument engineer's pipe dream.

With the attack on Pearl Harbor in 1941, the resources and personnel of the instrument industry were turned to the problems of modern naval and aerial warfare. The coordinated efforts of industry and the technical schools led to the development of servomechanism techniques. Some of the specific problems encountered involved dropping a bomb on a target from a moving airplane, stabilizing a rolling gun platform, controlling of massive radar antennae, and the positioning of guns for long range accuracy. Oversimplified, the essentials of these techniques were to measure continuously and accurately the deviation of the output from command and to continuously control the input signal to the system. For example, in the problem of stabilizing a rolling gun platform, the larger the measured deviation from horizontal, the larger would be the necessary force to correct the deviation. Further, these closed loop systems were designed to take advantage of instrumentation to the fullest extent, instead of merely superimposing instruments on existing systems.

Consider the problem of hitting a zigzagging enemy aircraft from the deck of a moving ship. First we need accurate information as to the relative position and velocity of the plane with respect to the ship. With this data we need to compute the plane's probable path in the immediate future, consider the trajectory of the projectile, and compute the necessary firing instant and position of the gun to hit the plane. Then we need to measure the deviation of the gun from this desired position, accurately position the gun, and then push the button. All this measuriug, calculating, and positioning must be done almost instantaneously. The resultant demand for better, more accurate instruments and controls led to the development of radar, computing machines, and servomotors.

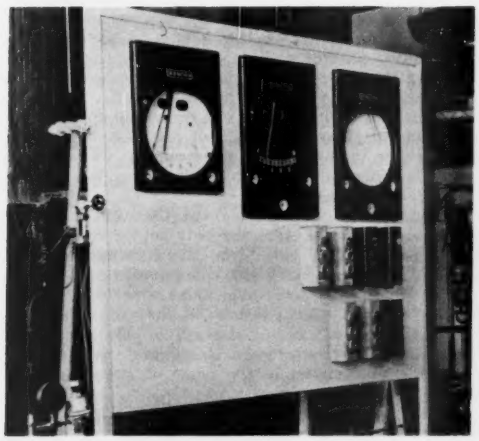
The control of the gun position and the radar antennae, while not the most difficult of the problems, was nevertheless similar to many in industry. That is, unless provided for, the gun would have a tendency due to momentum or time lag between measurement

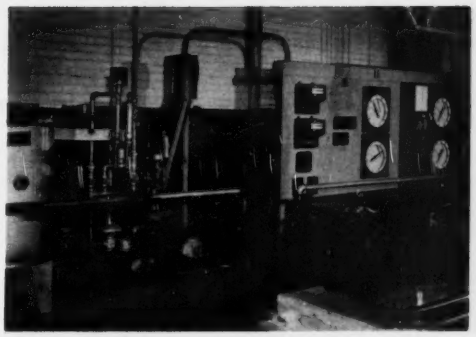
and control to go past the desired point, with a resulting deviation in the opposite direction. With this, the controlling mechanism would start the gun back, and the gun would oscillate about the desired position. The system had to be properly damped to overcome this effect.

With the declassification of much of the work done on automatic controls during the war, these techniques, which were germinated in the Thirties and developed under fire, were ready for application in the postwar expansion of the civilian economy. Demand for automatic controls by the expanding process industries was so great that the instrument makers, war expanded as they were, were unable to meet orders without further expansion. The industry as a result has grown to more than twice its prewar size. The advantages of automatic instrumentation and control are many. A processor who previously had to make his product in batches with highly paid craftsmen would, with the new techniques, be able to economize on plant space by doing away with space-consuming storage tanks and making his process continuous from beginning to end. Further, he could increase the productivity of his personnel by requiring less labor input for a given volume of goods. More important, these controls are now capable in many cases of holding the process variables within such small tolerances that waste, spoilage, power losses, heat losses, and rejects could be cut considerably; in businesses of great size, even a small increase in efficiency is measureable in millions of dollars annually.

One of the many applications of temperature controls can be found in the manufacture of sulfur dioxide. Here stability of operation is important to insure a constant concentration of the gas so necessary in the next process of manufacturing sulfuric acid. Since the oxidation of sulfur to sulfur dioxide is an exothermic reaction the temperature of the gas is roughly proportional to its concentration, if other things are held constant. By placing a thermocouple at the end of the combustion chamber, holding the rate of sulfur feed constant and regulating the rate of air intake in proportion to the deviations from a set point in the temperature of the gas (by electronic or pneumatic controls) the desired effects can be obtained.

Liquid level and specific gravity controls are used in the refining of sugar for peak output and performance.





Metal parts ready for heat treatment in automatically controlled furnace.

In the paper industry the quality of the paper produced is highly dependent on the pH of the stock. A variation in pH can effect the sheet uniformity, printing surface, finish, permanency, retention and uniformity of color. By means of pH electrodes placed in the lines so that there is a continuous sample being measured, and by automatically controlling the flow of alum or other reagent into the system in proportion to the deviation of the pH from the desired point, the pH of the stock can be held constant. With proper design the system automatically compensates for variations in the concentration of the alum solution or the pH of the incoming stock.

In the process of making frozen orange juice, the juice is evaporated under a vacuum until about three-fourths of its water content is removed. Quality control in this process demands as one of the criteria of a uniform product that the density of the final product be constant. The method of keeping this density constant is similar to the level control found in the ordinary water closet. A displacer of slightly less weight than an equal volume of standard concentrate is submerged in a chamber through which a continuous sample of the juice is passed. The displacer is connected through a lever to a bellows. A change in the density of the concentrate causes a change in the buoyancy of the displacer, which in turn changes the air pressure within the bellows. The deviation in this pressure is measured by a gauge which controls the amount of juice leaving the evaporator. The net result is that if the product is just a little too concentrated, more of the juice is taken out of the system, or if it is not quite concentrated enough, the rate of removal is decreased, thus keeping the density of the final product constant.

In the above industries and, in fact, in any process industry today, there are literally hundreds of applications or opportunities for further applications of automatic controls. These opportunities are limited only by the accuracy of the instrumentation and the characteristics of the controlling devices. In fact anything that can be measured and controlled by hand can be automatically controlled.

In the civilian economy outside of the process field, applications of feedback controls are found in automatic pilots, automobile voltage regulators, paper feed controls in printing presses, and elsewhere.

Undoubtedly, the military are developing more and better techniques for controlling guided missiles and pilotless aircraft. Further, the very nature of atomic research requires servomechanisms for control of these

(*Continued on page 26*)

the thermocouple

An Important Temperature Measuring Instrument

By Sol Aisenberg, G.

It has been found that if two wires of dissimilar metals are connected together to form two junctions, and if the junctions are maintained at different temperatures, a current will flow through the circuit. The electromotive force producing this current flow is determined by the nature of the metals forming the junctions, and the temperature of each. Obviously, if the exact relationship between the electromotive force and the temperature of the junctions is known for a given pair of metals, then the temperature of one joint can be calculated, provided that both the electromotive force of the couple and the temperature of the other junction are known.

A thermocouple has many advantages over the ordinary glass or metal expansion thermometer. It has a much greater temperature range because it is limited only by the melting point of the metals, and it can be made much smaller because the thermoelectric voltage developed depends only upon the two metals chosen and not upon their size. Because of the small size that is possible, the thermocouple can be used to measure the temperature of very small objects, and it may be used to measure small quantities of heat energy. In addition, it is used to measure temperature in places normally inaccessible to standard thermometers. This is possible because it is only necessary to lead two fine wires out to the measuring instrument.

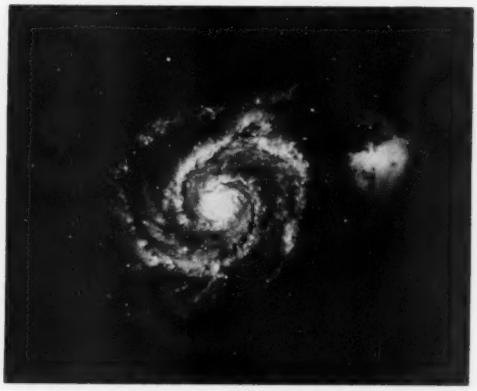
When a number of thermocouples are connected so that their thermoelectric voltages add up, the resultant thermopile has a sensitivity great enough to measure the heat coming from a single candle at a distance of over fifty miles, or the heat from a distant star. Using a thermopile made of 1,000 thermocouples, Lange was able to detect a temperature difference of 0.0000002 degrees Centigrade.

The accuracy and sensitivity of a thermocouple is dependent to a large extent upon the instrument used to measure the resultant electromotive force. The two basic types of measuring instruments are the galvanometer, which measures the current flowing in the circuit and the potentiometer, which measures the electromotive forces produced at the junctions. Since the first method requires a flow of current, there is an error introduced because of the resistance of the couple and of the lines connecting the couple to the meter. In the null-point potentiometer, at balance there is no current flowing through the couple. The true thermal electromotive force is thus obtained without the need for correction factors. Since the thermal e.m.f. is of a very small magnitude, the instrument must usually be able to measure the electromotive force accurately to within one microvolt.

Now that the methods for measuring the thermoelectric force of a couple have been outlined, the relationship between the e.m.f. and the temperatures will have to be determined. In order to produce a better understanding of the topic, the various thermoelectric effects will first be discussed.

An English scientist, J. P. Joule, proved in 1841 that the heat evolved per second in a metal conductor is directly proportional to the square of the current flowing in the wire. Since the heat evolved is a function of the second power of the current, the Joule heat is an irreversible phenomenon and is always positive, independent of the current direction.

In the year 1822 Johann Seebeck announced that if two dissimilar metal bars are connected and if one of the junctions is heated, a magnetic field is produced which indicates that there is a current flowing in the circuit. The work is done in the external circuit at the expense of the heat energy in the thermocouple.



The heat from this nebula, three million light years from the earth, can be measured by means of a sensitive thermopile.

The inverse of the Seebeck effect was discovered in 1834 by J. C. Peltier, a French scientist. Peltier found that when a current is passed through a thermocouple, one of the junctions is heated and the other junction is cooled. If the current is reversed, the conditions are also reversed; the first junction is now cooled and the second is heated. The Peltier heat is found to be proportional to the current flow, and this effect takes place whether the current is provided by an outside source or is generated by the thermocouple itself. It is thus seen that the Peltier effect is a reversible one because it is dependent upon the current direction and is proportional to the first power of the current. The Peltier effect is explained by assuming that there is an e.m.f. across each junction.

Lord Kelvin in 1851 showed that if the Peltier electromotive force were the only source of e.m.f. in the thermocouple, the Seebeck electromotive force should be proportional to the difference in temperature of the junctions. Since experience shows that this is not true, Lord Kelvin concluded that there must be another source of e.m.f. in the couple. He proved that the Thomson electromotive force is caused by the unequal temperature of the parts of a single bar of metal. When one end of a homogeneous conductor is

(*Continued on page 26*)

the calculus of significance values

The Formalization of Sense and Nonsense

By D. F. Schroeder

Statements are ordered collections of symbols. Whether the statement is made in mathematical or in verbal terms, these symbols are used in accordance with a predetermined system of syntax; that is, according to certain well defined rules of the game. A statement is said to have significance if its elements and their manner of combination obey these rules; otherwise it is said to be meaningless. Similarly, a theorem, considered as an ordered pair of statements, to wit, hypothesis and conclusion, may take on one of three distinct significance values. These are definitions: a theorem is true if its hypothesis and conclusion have meaning, and if the hypothesis implies the conclusion under the rules of the game; a theorem is false if the hypothesis and conclusion lie in the realm of meaning, and if the hypothesis does not imply the conclusion; a theorem is nonsense (a) if either the hypothesis or the conclusion or both are meaningless, or (b) if the hypothesis implies both the conclusion and its opposite.

A word about the notation to be used in what follows. M will represent the set of meaningful statements, R the given syntax, Greek letters will be used for theorems, Roman for statements. $A + B$ shall represent the logical sum of A and B, read "Either A or B"; AB shall denote the logical product of A and B, read "A and B"; and A' shall denote the negation of A, read "not A."

With this notation, the definitions become:

(1) α is true if H, C, lie in M, and if H implies C under R (i.e., $H' + C$ under R).
(2) α is false if H, C, lie in M, and $(H' + C)'$ under R.
(3) α is nonsense if (a) H or C does not lie in M, or (b) both $H' + C$ and $(H' + C)'$ under R.

H always represents the hypothesis, C the conclusion.

With this basis, using for the most part the conventional procedures of symbolic logic, that branch of mathematics known as the calculus of significance values has been developed in the past generation largely through the labors of three men on three continents.

The first major work in the calculus of significance values was that of the English algebraist Thompson in 1933. Thompson, who took up mathematics as a hobby when already past what most men would consider retirement age, performed notable work in laying foundations. He defined an operation, subsequently known as the Thompson product, which mapped pairs of theorems into a third as follows:

$$\alpha + \beta = \gamma, \text{ where } H_\alpha + H_\beta = H_\gamma$$
$$C_\alpha \quad C_\beta = C_\gamma$$

It is at once evident that $\alpha + \beta$ is indeed a theorem; that the operation is commutative and associative is likewise trivial. Space considerations prevent the presentation of proofs of the following less obvious results.

Lemma 1 (Dever-Thompson): The product of a finite number of nonsensical theorems cannot be true.

Lemma 2 (Thompson): The product of a true theorem and a false theorem is true if and only if the false theorem satisfies the Thompson criteria.

These lemmas (the "twin lemmas," as they are called) suffice to prove the following powerful theorem of Thompson:

Theorem: The product of any number of nonsensical theorems can be false.

The work of Thompson, his co-worker and son-in-law Dever, and others, constitutes the basis of all the subsequent research of J. Fleischer, the brilliant South African mathematician, whose timely death in 1939, at the height of his powers, was a severe loss to the then new science of nonsense. Of all of Fleischer's rich and varied output, perhaps most noteworthy is his supposed corollary to the theorem of Thompson. This corollary, known today as the Fleischer Conjecture, was refuted by Niles, but not before it had caught the imaginations of thousands of pioneering workers in the field of science fiction.

Briefly, the Fleischer Conjecture states that the possible number of nonsensical theorems over a Benson-articulated syntax R is non-denumerable. Had Fleischer's "proof" been correct, it is entirely possible that results of significance-value theory could have been applied to seemingly unrelated branches of mathematical investigation: in particular, the problem of proving a given number transcendental would have been perhaps reduced to a canonical procedure.

Besides this refuted theorem, a large body of Fleischer's work was of the greatest import to the development of the field. The study of the tautology that he carried on in his last years, his ingenious proof of the sufficiency of hyper-complex articulation for a syntax to be free from ζ-nonsense theorems, constructions of the fourth-degree-falseness theorems whose existence had been proved by Thompson, all these and others mark Fleischer as a theorist of the first order.

With Fleischer's passing, followed soon by the outbreak of the war, the development of the calculus of significance values entered a fallow period. After 1939, research was almost at a standstill until the spring of 1947. At this time appeared the first papers of J. A. Niles, which may be said to have quantified significance theory. Niles introduced a measure that could be applied to certain sets of theorems, by what may be described as a generalization of the crude idea of "strong" and "weak" theorems. Applied to sets of theorems, and collections of such sets, Niles obtained results that are still the subject of vigorous discussion. No one who lived through that period can forget the repercussions of the following three theorems, published within a period of sixteen months:

Theorem: Every true theorem has a measure, quasi-unique in the sense of Niles.

Theorem: The measure of a denumerably infinite set of true theorems over any D-syntax is infinite.

Theorem: The measure of a denumerable collection of sets of infinitely many nonsensical theorems over any syntax has a finite least upper bound.

Let us close on this hopeful note.

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from the editor's notebook

Think Before You Sign!

As practically every Techman knows by now, the United States Government decided to revoke all ROTC contracts last month and offer new ones to everyone in the corps. The new contract was virtually the same as the old one; there is still the requirement of two years' service in the active reserves after graduation. The only new feature is a term of eight years' service in the active reserves after graduation, which would probably not inconvenience anyone except in time of war. The new contract principally served to force the issue; the student had to decide definitely to take advanced ROTC and accept a commission or resign from Military Science after basic training.

Few of us will ever have to make a single decision affecting eight years of our lives again. I hope that no one will be forced to do so under the conditions that prevailed in this case. The false sense of urgency, the minimization of the importance of the contract, and the completely conflicting advice that arose from various sources, all served to promote a hasty, ill-advised choice.

Some members of the Military Science Department were particularly reprehensible in their efforts to obtain a large number of signatures. On the first day that the new contracts came out, one officer passed them out to his freshman class and told the students to sign them and return them immediately. Practically all of his unwitting victims placed their John Hancocks in the proper places and handed the documents back with hardly more than a minute's glance (it was almost a page of solid type — much too long to read!). Another officer told his cadets that they could pick up their monthly pay checks *after* they had signed the contracts, even though they were entitled to the money regardless of the signature. Some of the cadets were given the impression that they could discuss the matter with their parents and draft boards over the Christmas vacation, only to be given four days' notice that they must make their final decision before the holidays. Such types of pressure were generally quite effective in forcing hasty decisions.

Students in ROTC classes were also told that the draft is inevitable for everyone, and that signing the contract was a matter of simple arithmetic; a lieutenant's pay is considerably above a private's. Fine. But those who bothered to go to Mrs. Lutz, the school Adviser on Military and Selective Service Affairs, got a completely different picture of the situation. Mrs. Lutz flatly states that she can practically guarantee that anyone with good grades will at least graduate. An essential job or admission into graduate school assures deferment from the draft. Go into the Army as a private? *Very* small chance. One leaves her office much less sure about the desirability of the free uniform that is being offered. In fact, one wonders whether Mrs. Lutz and the military personnel are talking about the same draft law.

Which course is best? I can't say; certainly it varies from case to case. Each individual must decide for himself. But above all, he must consider all of the aspects of his particular problem and the consequences of each course of action. Then he can sign or not as he pleases, but his decision will be based on thought and not simply the path of least resistance. The present situation is typical of all of the big decisions that we will have to make; there will always be various groups tending to influence us one way or another. No one group should try to hasten us into a decision, but some of them will. If we do act hastily, the blame belongs to no one but ourselves. We should take the trouble to think a little before we do anything, even outside the laboratory or classroom.

J. M.

nuclear powered aircraft

(*Continued from page 5*)

in the heat removal capacity of the heat transfer system, the reactor inevitably will heat up. Over-heating, if sufficiently severe, can cause accelerated corrosion, warping or even melting of parts of the reactor. Evidently, it is important that the reactor not be operated without a flow of coolant through it, since this certainly will result in serious damage if not destruction of the reactor.

Although most of the energy of nuclear fission appears as kinetic energy of the two fission fragments mentioned above, a substantial portion of the energy appears as kinetic energy of the neutrons and as ionizing radiation, such as gamma rays and beta rays. The neutrons and gamma rays, if allowed to escape with complete freedom from the reactor, would make it necessary for human beings to stay at a distance of more than a mile from a high powered reactor while in operation. Moreover, since the fission products themselves are radioactive and continue to emit gamma rays even after the chain reaction has been stopped, it would not be possible to approach the reactor very much closer than this even after it had been shut down. It is clear that a shield must be provided.

The basic requirements of the shield are dictated by the two basic types of radiation which it is desired to stop. The neutrons are slowed down most effectively by light atoms such as hydrogen, and moreover are more easily captured after being slowed down. Gamma rays, on the other hand, are degraded in energy and stopped best by heavy elements such as lead. Hence, the shield normally will contain both heavy elements and hydrogen. The details of the arrangement are not particularly important for a large stationary reactor such as those which have been built on the ground in the past. However, for a reactor which is to be mobile, it is important that the shield weight and dimensions be kept small. Hence, the materials put into the shield must be of the best possible quality and must be arranged in the best possible fashion. The detailed solution of this problem is extremely complicated.

Another point of importance is that not only must the shield prevent escape of radiation from the reactor to the desired degree, but also it must be capable of admitting and emitting the coolant. This means that ducts must pierce the shield, causing leakage of radiation. Generally speaking, gamma rays and neutrons travel in straight lines. However, under certain conditions they can be scattered around corners or curves. This confronts us with another difficult but interesting problem in the shield.

Some difficult problems in addition to those mentioned above confront the designer of a nuclear powered aircraft.

The shield will be the heaviest single object aboard the aircraft. Early published estimates of shield weight placed the minimum shield at fifty to one hundred tons, without any provisions for removal of heat. From this it is evident that a large aircraft will be required to carry a weight of this magnitude even though it need carry little or no chemical fuel. To a first approximation one may compare the weight of the shield with the weight of the fuel load which would be carried in the large modern aircraft, since the shield and the reactor which it contains essentially replace the fuel load. The fuel loads of modern aircraft range up to the neighborhood of seventy-five tons or more. If the early estimates of shield weight referred to above are anywhere near correct, it is evident that the weight of the shield plus the reactor is not grossly different from that of the fuel which can be carried in a large conventional aircraft. However, every effort must be made to keep down the weight of the shield and the reactor. One obvious way to do this is to make the reactor small so that the shielded volume is kept small. This in turn restricts the amount of cross sectional free flow area through which coolant may pass through the reactor and increases the pressure drop. Moreover, as the reactor diameter decreases it usually is found that more fissionable material is required. This is undesirable. There is, therefore, a balance to be struck between the benefit of small shield weights resulting from decreased reactor size on the one hand, and the disadvantages resulting therefrom in smaller free flow area for coolant flow and larger fissionable material investment required.

The existence of a large concentrated weight such as the shield and the reactor at one point in an aircraft makes it necessary to redesign the structure to accommodate this weight. Although large aircraft are designed for very large gross weights, this is usually distributed over the wing and throughout the fuselage. Concentrating the weight in the fuselage greatly increases wing bending moments and necessitates structural redesign in many cases.

The very fact that only a small amount of the fuel is consumed in flight means that the gross weight of a nuclear aircraft will be approximately the same on landing as on take-off. Therefore, the landing gear must be made strong enough to take the higher gross landing weight.

The very essence of a nuclear power plant is the transfer of heat from the reactor to the propulsion machinery. The requirements for small size and high power density placed upon the aircraft reactor push the heat transfer designer to the limit of his knowledge. He must avoid hot spots in the flow system, he must have good flow distribution and he must know exactly how the power is distributed in the reactor so that he can supply the right amount of coolant to each part of it. Solution of these problems requires a great deal of detailed analysis and experiment. For example, consider the cooling of a surface beneath which U-235 is located in a reactor. The rate of heat generation is independent of the local temperature, thus if the surface be deprived of its coolant it will at once rise in temperature until it melts or disintegrates. The reactor is like a heat exchanger to which heat is constantly supplied whether it is taken away or not; only by maintaining the flow of coolant can trouble be avoided.

The desirability of keeping the quantity of fissionable material in the reactor small has been mentioned previously. However, the chain reaction will go only so long as there is present a certain minimum quantity of fissionable material called the critical mass. As soon as the reaction has consumed so much fissionable material that the mass drops very slightly below the critical mass, the chain reaction dies. Moreover, the products of fission remain in place in the fuel elements and eventually must be removed. This makes it necessary to remove the remaining fuel from the reactor, purify it and prepare it for reuse. The amount of uranium which may be tied up in the reprocessing activities may easily exceed that which is tied up in the reactor proper. Thus, the uranium investment is not simply the amount of uranium carried aboard the aircraft but also that which is on the ground in various stages of preparation for use. The question of recovery

(*Continued on page 16*)

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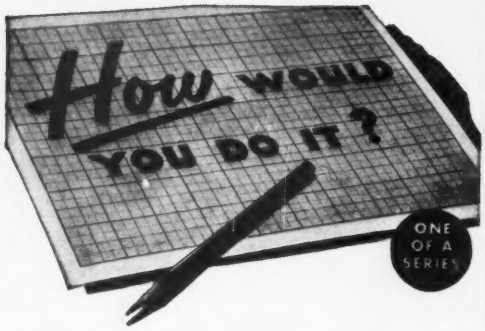

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nuclear powered aircraft

(Continued from page 14)

and reprocessing of the fissionable material is a matter for the chemist and chemical engineer, and is a whole new subject on which I shall not touch further here.

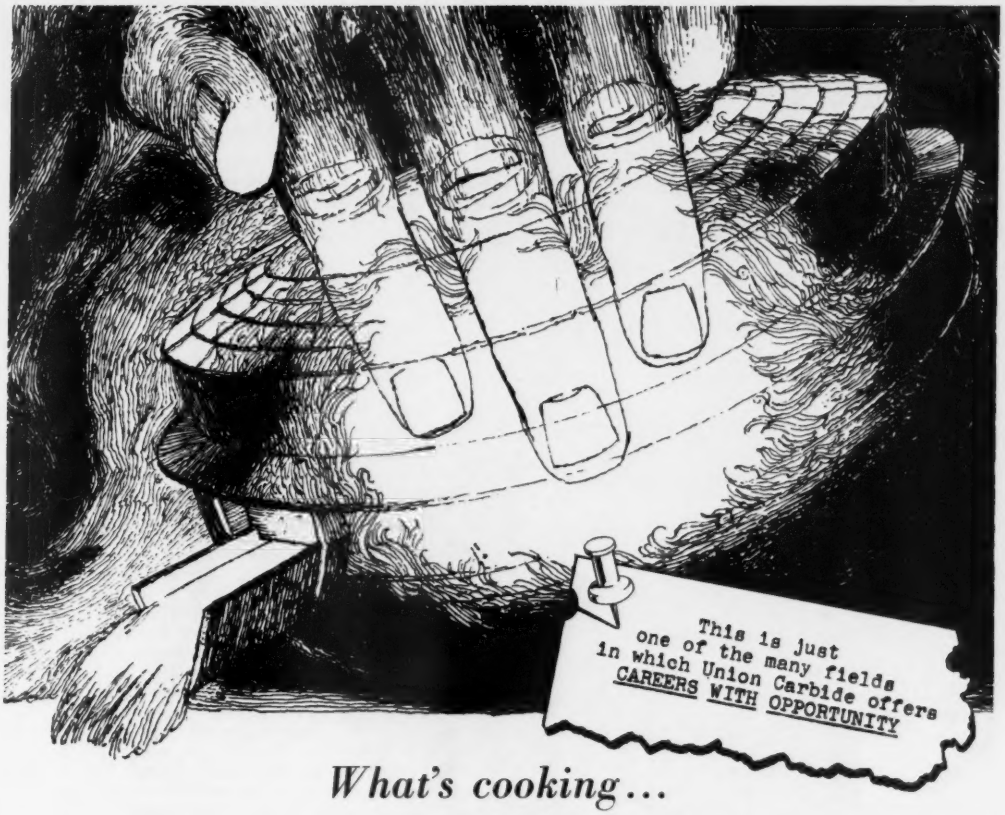
Inter-nuclear collision between neutrons and the nuclei of materials used as structures or as moderators in the reactor or between fission fragments and other nuclei result in dislocation of the nuclei with which collision occurs. While it is not definitely known how great an effect these dislocations have it is known that the properties of the materials in which they have occurred undergo a change. Usually this change is in a detrimental direction. For example, a decrease in thermal conductivity may occur, thus making the heat removal problem even harder.

Some liquids or gases which might be proposed as reactor coolants are decomposed by radiation, and are hence not usable. Organic compounds are particularly susceptible, and even outside the zone of most intense radiation in the reactor ordinary lubricants turn tarry or even solidify. Lubricated machinery hence may not be used in such locations. Electrical insulation, on prolonged exposure to radiation, breaks down and disintegrates or loses its effectiveness.

It is evidently necessary to confine substantially all the radioactivity of the reactor within it. This imposes another restriction on the designer of the reactor. It is occasionally suggested that a nuclear aircraft will create a hazard to population in its vicinity. Inasmuch as the aircraft itself will carry a crew which must be protected adequately, persons at a distance will not be affected in any way.

One of the most important problems in reactor technology today is the development of materials adequate for use in reactors. The combined effects of high temperature, corrosion by various coolants, radiation damage, thermal stresses, and mechanical stresses can be extremely serious in some cases. The aircraft reactor presents these problems to an unusual and critical degree. For example, a difference of 100° F. in permissible maximum reactor temperature can easily produce a 15 per cent difference in thrust output of the power plant. High temperature materials are therefore a prime necessity. A corrosion resistant coating on the reactor heat transfer surfaces a few thousandths inch thick may double the critical mass. A brazing alloy containing a few per cent boron (a strong neutron absorber) may put so much boron into the reactor that it cannot be made to go critical, and this particular alloy may therefore be entirely unusable. An alloy high in nickel may have good corrosion and high temperature strength properties for use as reactor structure, but be so strong a neutron absorber as to be substituted by another alloy of lower nickel content and poorer corrosion and strength properties. The finding of materials adequate to withstand these conditions is a challenge worthy of the best metallurgist, ceramist or chemist.

In many respects the propulsion of aircraft is an ideal use for nuclear energy. Here to a higher extent than in any other application the advantages of a highly concentrated source of heat can be used to good result. Although the goal of producing a nuclear powered aircraft is an admittedly ambitious one, it is only such high performance, premium uses of energy which can today justify the consumption of as rare a resource as uranium-235 or plutonium-239. Moreover, it is inescapable that a development of this type has great military significance.



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some elective courses

(*Continued from page 6*)

diophantine equations are briefly discussed. Polynomials and complex numbers are touched upon. Group theory is covered rather thoroughly, as are vectors and vector spaces. The algebra of matrices is then dealt with in quite a bit of detail. Rank and determinants are discussed in conjunction with the methods of solution of simultaneous linear equations. In each of these topics, many theorems are stated and proved; the problems try to develop in the student the ability to prove rigorously certain theorems or corollaries to the material taken up. If one is familiar with the rigorous approach to the solution of problems, then the course ought not to offer too much difficulty, but the problem assignments are long and will generally require five to six hours per week. If one has had no or very little rigorous mathematics, he can expect to spend around eight hours per week on the problems. The course is officially rated as a 3—6.

The textbook is *A Survey of Modern Algebra* by Birkhoff and MacLane. Unfortunately, it has several faults. One is the use of concepts without accurately defining them and instead forcing the student to use his intuition to picture them. Furthermore, the proof of a theorem is not always clearly indicated as such. Thirdly, and by far the worst, the wording of the problems is such that the student is not always sure what result a particular problem is after. In fact, at times it takes as long to decipher the problems as it does to solve them. However, the instructor, who has taught the course for four semesters and who is one of the best in the Mathematics Department, easily makes up for the textbook.

Finally, a few trivialities. There are three-hour quizzes and a final. They are very fair; about as fair as tests can be. Incidentally, the homework grader does not go at it in M11 style; he takes pains to point out where the student made his mistake. The competition is rather rough due to the mathematics students, both graduates and undergraduates, who are accustomed to the rigorous methods of mathematics.

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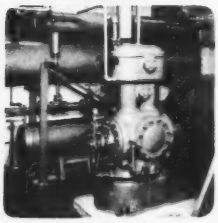

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(*Continued on page 20*)

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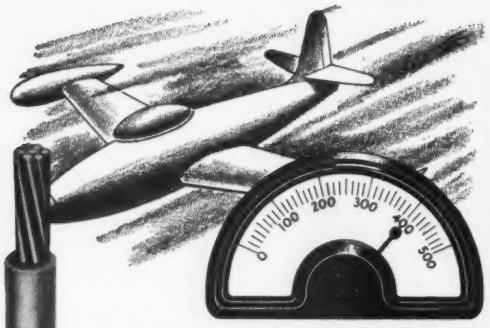

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some elective courses

(*Continued from page 18*)

few years has been upwards of two hundred students.

The subject material for the lectures is mainly the vocabulary of music: harmony, form, and so forth. This material is illustrated by the music in the listening assignments, which covers the whole history of Western music, from Gregorian chant to Hindemith's "Mathis der Maler." The catalogue lists five hours of preparation per week, an accurate estimate. However, since the listening may be done at your convenience in the Music Library, the homework assignments in E45 aren't the chore that most Institute work quickly becomes. These listening assignments, plus readings in Aaron Copland's "What to Listen For in Music" and class notes, make up the homework in E45.

Several quizzes are given during the term, but these are not at all vicious if you're reasonably well up on the assignments. The teaching is quite good; the important things to listen for are pointed out in the lectures, which are illustrated both with the recordings and by piano performances by Professor Tucker of excerpts from the music under discussion. The course on the whole is quite free of the arid pedantry which characterizes "Music Appreciation" courses in some other schools, and likewise free from the cute approach favored by the writers of program notes, who usually attempt to analyze music in terms of the psychological state of the composer at the time of composition. A new member of the instructing staff, Mr. Rickard, is available in the Music Library most of the time to answer individual questions.

F. T. C. Bartels, '53

flight without power

(*Continued from page 7*)

principles will clarify the significance of glider development up to this time. First, the lift L and the drag D are given by the following equations:

$$L = kC_1Sv^2 \text{ and } D = kC_dSv^2$$

where k is a proportionality constant, S is wing area, v is speed, C_l is a lift coefficient depending on the aerodynamic properties of the wind, and C_d is a drag coefficient depending on the streamlining of the whole plane. Now the first important factor in lighter-than-air development was the lift coefficient of the wing. Flat wings were almost useless, as seen by the fact that 95 per cent of the lift of modern airfoils comes from the pressure difference between the top and bottom of the wing caused by the increased air velocity over the top of the airfoil. (Bernoulli's Equation). The failure of most of the experiments before 1800 was due to the use of flat wings. The second way to increase the lift was by increasing wing area. This method was carried to the farthest extent possible by the early experimenters, who sacrificed maneuverability and strength for wing area. The early, twelve-winged gliders of Chanute are a good example of this trend. The third method of increasing lift, by increasing velocity, depended chiefly on the launching method. Thus, improved methods of towing the glider into the air had a very great effect on lift. Also the addition of power to flying acted on lift sufficiently through velocity to offset the additional weight.

$$\text{Now: } \frac{L}{D} = \frac{C_l}{C_d} = \frac{V_f}{V_s} = \cot\theta = \text{gliding ratio}$$

where V_s = sinking speed, V_f = forward speed,

θ = angle of glide, and gliding ratio = $\dfrac{\text{distance forward}}{\text{altitude lost}}$

The gliding ratio, which determines the distance flown by the glider starting from a given height, can be increased by increasing lift or decreasing drag, but does not depend on weight. So the short distances attained by the early types of gliders were due, to a large degree, to the wind resistance offered by the pilot.

The chief drawbacks of early gliders, and even the later Wright models, were: first, high drag coefficients; second, insufficient lift coefficients; and third, low speeds. The lack of stable controls in the earlier models had been largely ironed out in the Wright glider experiments.

The above listed faults in gliders were largely carried over into powered planes. It was perhaps unfortunate that powered flight developed so soon from motorless flight, for the early power plane designers took over the frame construction of the best performing gliders, and at first made a few structural improvements, concentrating instead on the production of more horsepower. Thus, the availability of more than adequate power allowed faulty aerodynamic design to take to the skies. The advent of the First World War greatly aggravated this tendency, as an examination of photographs of early warplanes will show. Drag was too high, and full lift capacity was not tapped. Gliding ratios were dangerously low. The military planes were too dangerous and expensive for transition to civilian flight.

To develop aircraft on a more efficient aerodynamic basis, and to avoid some of the restrictions of the Versailles treaty in training pilots, Germany turned again to gliding after the War. Annual glider meets

(*Continued on page 22*)

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flight without power

(*Continued from page 20*)

were held on the Wasserkuppe site. The first meet, in 1920, attracted entries ranging from Lilienthal hang type glider to reconverted Fokker warplanes. But a few entries which embodied streamlined design and new principles, notably the entry of Wolfgang Klemperer, swept the honors and led to widespread imitation in design. In this contest was introduced the newly perfected shock cord launching system by means of elastic ropes and twelve-man launching crews. The meet aroused enough enthusiasm to ensure the future of gliding in Germany.

In the next few years more gliders of the improved covered fuselage type were constructed, and the first actual sailplanes of high gliding ratios, above twenty to one, were built. Then new methods in soaring technique began to be developed. For some time glider pilots had known of, and had attempted to utilize, the updrafts caused by the upward deflection of a steady wind from a steep hill, but the German pilots managed to improve slope and ridge soaring to raise the duration record to twelve hours by 1925. But now the soaring pilots began to utilize updrafts under cumulus clouds and "thermals," or natural updrafts from hot air over plowed fields, houses, or the like. Now the glider pilot became almost a free agent, being able to soar almost indefinitely in favorable territory.

German gliding was by this time state subsidized, the government realizing the value of gliding for pilot training and aeronautical design. The gliding fraternity was now made up of three groups, engineers, sportsmen, and students. The engineers and sportsmen contributed to advanced design, as well as setting new speed, endurance, and distance records. Thousands of schoolboys took advantage of the free, state subsidized gliding lessons. New methods of launching were developed. The winch tow, in which the glider is launched by a wire which is rapidly reeled in by a motor driven spool, increased takeoff ceilings to a thousand feet and more. Airplane tows, which could start the glider at almost any height, enabled the crossing of the English Channel by glider in 1936.

Partly because of her lead in glider activity, Germany led the world in aeronautical design. The airplane designers of the Thirties came from the ranks of glider enthusiasts of the Twenties, and Hitler built his Luftwaffe with pilots who had received their basic training in gliders.

Meanwhile, in the United States, interest in gliding, which had almost vanished since the first Wright experiments, slowly began to revive in the Twenties. In 1920, the M. I. T. Glider Club was formed by several aeronautical engineering students. They constructed several gliders and sent one of them, piloted by Edmund Allen, later to take a leading part in the development of the B29, to Europe, where he gave several exhibitions in France and entered the 1922 competition at the Wasserkuppe. Unfortunately, his glider was left decorating a treetop in the course of the competition. Other members of the early M. I. T. Glider Club were Richard DuPont, later for a time world distance soaring record holder, and Otto Koppen, now Professor of Aeronautical Engineering here at the Institute. Thus here, as in Germany, gliding attracted many men who later became outstanding in the aeronautical world.

But gliding never attained much stature in this country until 1928, when several German soaring pilots came over with the first modern sailplane seen in this country. With it they made a soaring flight of more than four hours over the sand dunes of Cape Cod. In the following years American gliding was stimulated by the manufacture of American designed gliders. In 1930, the first of the annual United States National Glider Competitions was held at Elmira, New York. In the decade before 1940 American glider designs and records improved tremendously.

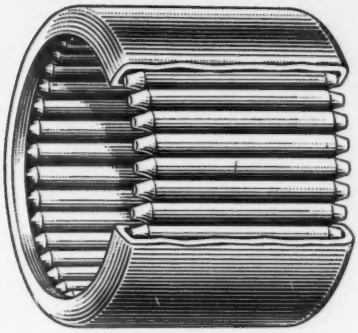
During the last war, there was intensive development of transport gliders which could land in small fields to support paratroops. The military also improved airplane towing so that one motored transport plane could tow up to three gliders. The most notable use made of military gliders was in our invasion of Sicily.

The M. I. T. winch in action.

The sale of surplus military equipment aided the revival of gliding in this country after the war. New clubs were formed, and records began to fall. In January 1950 two Americans set a new world two-place glider altitude record of thirty-six thousand feet, in a flight over the Sierra Nevada mountains. In June of 1951, Richard Johnson, the United States national soaring champion, set a new world distance record of 545 miles.

The rapid growth of interest in gliding in recent years has been aided greatly by the increased supply of gliders. In addition to surplus military trainers, there were the gliders made by facilities reconverted to peacetime use. The place of the open framework primary glider formerly used for training was taken by the more streamlined utility glider, which, with a gliding ratio of sixteen to one, or better, could also be used for soaring. Since these utility planes can be easily disassembled and placed on trailers for transport, they are an ideal club ship. Also, many sail-planes and high performance ships were built with gliding ratios of well over twenty to one. Also, airplane tows are frequently used for launching, and wing construction and launching technique have been improved.

The M. I. T. Glider Club has kept up with developments in motorless flight, especially in wind development. In 1934, several members perfected a winch, reconverted from a stripped down automobile, in which the power for the drum was taken from the rear wheels instead of the transmission. This type winch provides surer power control, since the driver is facing the glider, and is now widely used. The club now has two winches of this type, two single place utility gliders, and one two-place utility glider with dual controls, used in training beginners. The club has also leased a power plane which will be used for airplane tows this spring when a towing license has been obtained.



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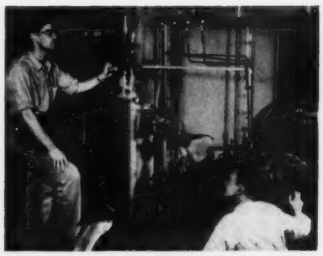

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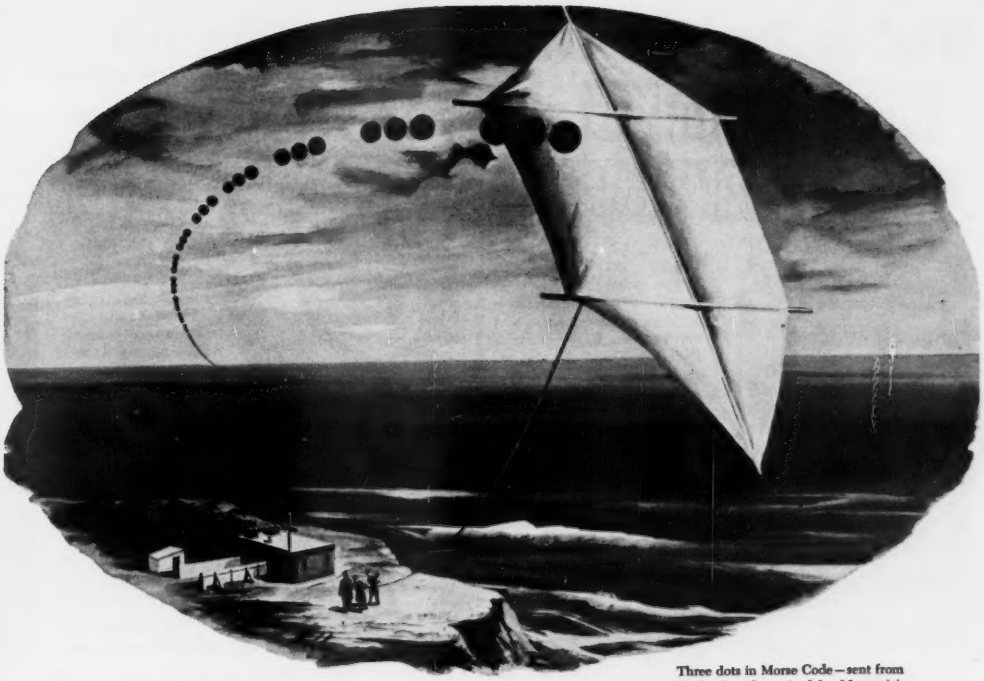

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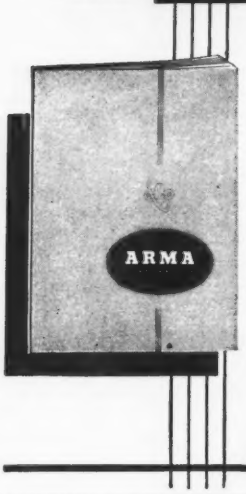

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machine replaces man

(*Continued from page 9*)

processes. The instrument industry today is under strict military security regulations, and is currently working on heavy defense contracts. With the increasing use of feedback controls in the process industries and for defense purposes, the instrument makers are suffering growing pains. Most of them could use about twice as much plant space as they currently employ.

Automatic instrumentation, besides reducing operating costs of existing processes, has also brought many previously impractical or impossible processes into use. At the present time fifty million dollars worth of automatic equipment controls a yearly output of fifty billion dollars worth of products. There are factories in operation in the chemical field which can be operated completely by one man sitting behind a control panel, whose duties are to record the readings, start the plant up at the beginning of the week, shut it down at the end, and otherwise not to touch the controls except in emergencies. These, however, are in the minority because many processes involve too many variables for completely automatic control.

With the development of electronic computers which can handle variables fed directly into the computer without requiring that the information first be punched onto cards, and which have the ability to produce answers as fast as the information is fed in, the completely automatic factory is quite possible. Such a machine is the JAINCOMP-A recently developed by the Jacobs Instrument Company. Professor Norbert Weiner has said that such a device, if ever fully developed, would usher in the second Industrial Revolution. Only time will tell.

the thermocouple

(*Continued from page 10*)

heated, the electrons at that end have their energies increased and an electron redistribution takes place. The heated end becomes positively charged, since electrons flow to the cold end until the electric gradient caused by the displacement of the charge is sufficient to counteract the effect of the temperature gradient. Thus we see that merely heating one end of a wire is sufficient to produce a Thomson e.m.f. The Thomson effect, which is the production or absorption of heat by the wire, is also reversible because it is proportional to the first power of the current in the wire.

In conjunction with the Peltier and Thomson electromotive forces the following should be noted: when the current in the circuit flows against the electromotive force, heat is liberated; however, if the current flows in the direction of the e.m.f., heat is absorbed.

For the sake of clearness the case of homogeneous metals only, was considered. Thermoelectric properties are very sensitive to various physical and chemical factors. Small amounts of impurities, mechanical strain, magnetic fields, and temperature changes, all have profound effects on the thermoelectric e.m.f. The thermoelectric characteristics of some thermocouples are strongly dependent upon the orientations of the crystal structures.

The Seebeck voltage is the algebraic sum of the Peltier and Thomson electromotive forces. Tait found that for most metals, the e.m.f.-temperature curves are approximately parabolic, thus indicating that a quadratic equation could be used to represent the conditions for most metals.

GIGANTIC

NEW HYPERSORBER

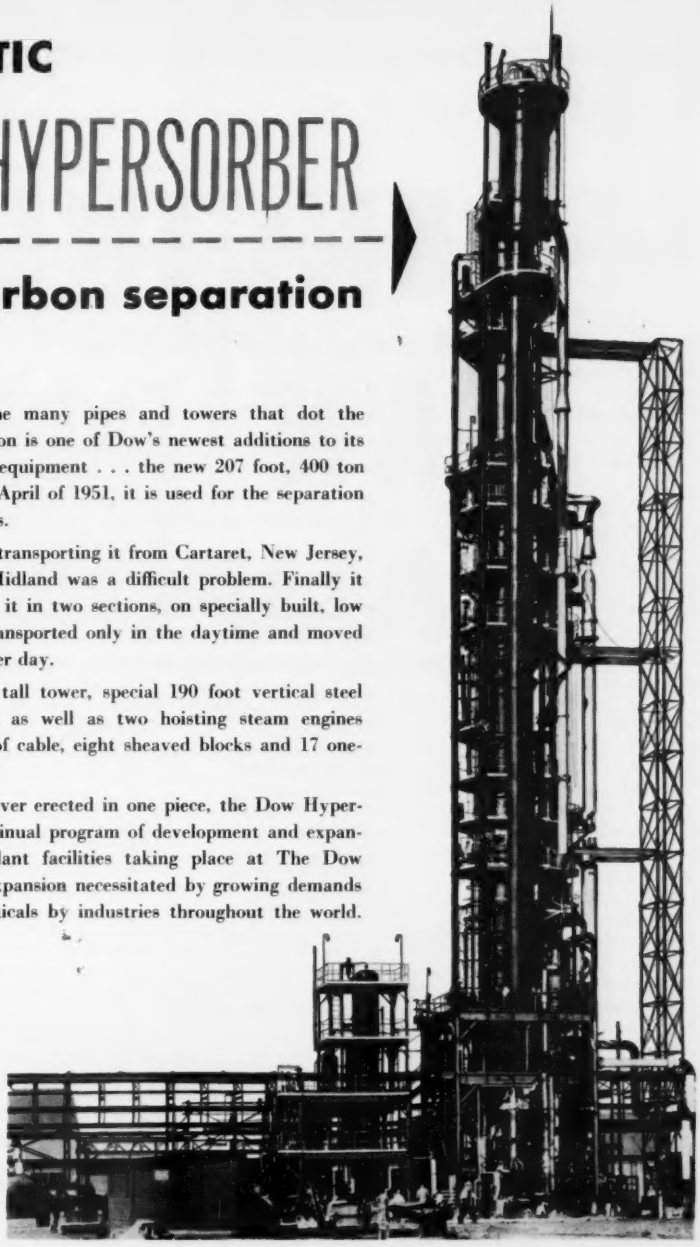
for hydrocarbon separation

Towering high above the many pipes and towers that dot the Midland, Michigan horizon is one of Dow's newest additions to its vast supply of technical equipment . . . the new 207 foot, 400 ton Hypersorber. Erected in April of 1951, it is used for the separation of light hydrocarbon gases.

Because of its huge size, transporting it from Cartaret, New Jersey, where it was made, to Midland was a difficult problem. Finally it was decided to transport it in two sections, on specially built, low slung rail cars. It was transported only in the daytime and moved no more than 100 miles per day.

For the erection of this tall tower, special 190 foot vertical steel columns were employed, as well as two hoisting steam engines controlling ¾ of a mile of cable, eight sheaved blocks and 17 one-inch cables.

The largest single drum ever erected in one piece, the Dow Hypersorber is part of the continual program of development and expansion of technical and plant facilities taking place at The Dow Chemical Company . . . expansion necessitated by growing demands for its high quality chemicals by industries throughout the world.

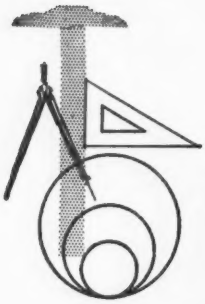


Dow's booklet, "Opportunities with The Dow Chemical Company," especially written for those about to enter the chemical profession, is available free, upon request. Write to The Dow Chemical Company, Technical Employment, Midland, Michigan.

THE DOW CHEMICAL COMPANY

Midland, Michigan

DOW
CHEMICALS
INDISPENSABLE TO INDUSTRY AND AGRICULTURE



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SAN DIEGO

that sunny, beautiful coastal city in

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Positions Now Open

Design Engineers
Design Draftsmen
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Microwave Engineers
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Weight Engineers
Aerodynamics Engineers
Test Engineers
Thermodynamics Engineers

Convair also has a limited number of attractive openings for recent engineer graduates: Aeronautical, Mechanical, Electrical Engineering and Civil Engineering interested in Aircraft Structural Design.

Working Facts

You get two holidays a week at Convair — overtime accomplished in 5-day week. Attractive salary ranges. An "engineers" engineering department... with stimulating, competent associates ...and interesting, challenging, essential, long-range projects of a wide variety including — commercial aircraft, military aircraft, missiles, engineering research and electronic development. Excellent patent royalty arrangements. Top-notch retirement plan — better-than-average life and health insurance. Complete progress-salary review for each person twice yearly. Opportunity for continuing engineering education.

If you qualify, you will receive generous travel allowances.
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THANK YOU

Mr. H. T. Brooks, Engineering Department N
Convair, 3302 Pacific Hiway, San Diego 1, California

Please send me FREE booklets describing the Convair Opportunity for me and my Convair Application Form.

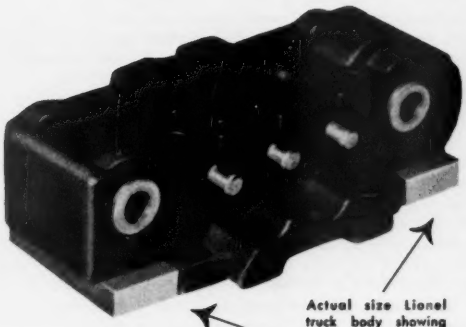
My name _____

Address _____

City _____ **State** _____

What's Happening at CRUCIBLE

about permanent alnico magnets



Actual size Lionel truck body showing two Crucible alnico bar magnets in place.

Lionel uses Crucible Alnico in new locomotive design

The Lionel Corporation, big name electrical toy manufacturer, has pioneered in the design of miniature locomotives for table-top railroading. One of the principal aims of this design is to achieve the highest possible degree of adhesion between the driving wheels and the track.

Lionel experimented with a conventional method of increasing the traction (i.e. load up the driving axles with ballast weights) . . . and then turned to magnetic materials.

Crucible alnico specialists were called in. Working in close cooperation with Lionel engineers, the Lionel "Magne-Traction" locomotive was born. As the name implies, "Magne-Traction" utilizes magnetic attraction between powerful Crucible alnico bar magnets placed in close proximity with the wheels.

By varying the number and strength of the magnets, almost any desired degree of adhesion can be obtained. In laboratory tests a light-weight plastic "Scout" locomotive whose normal train load is 4 cars, was able, after installation of proper magnets, to pull a train of 24 cars, an improvement of 600%. A heavy miniature locomotive

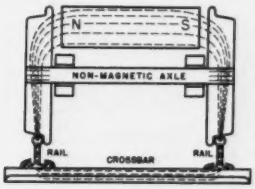


Diagram shows how magnetizing force is supplied by external stationary Crucible permanent magnet and non-magnetic axle. Wheels are sintered steel.

pulled 28 cars instead of its usual load of 7 cars. Then too, locomotives unable to start a normal 4 or 5 car train on greater than 1 degree slope were able with the special magnet assembly to pull them from a dead start up a 5° slope, while the new twin-motor Lionel Pennsy GG-1 scooted up a 15° slope (i.e. 37% grade) without any apparent difficulty.

Crucible's part was twofold. Not only were Crucible metallurgists and engineers active in the initial design, but Crucible production experts precision cast these bar magnets using plastic patterns. This is an innovation in alnico magnet mass production. Commonly, alnico is made in sand molds, and usually requires a great deal of finishing, but with precision-cast alnico magnets expensive machining is cut to a minimum.

Engineering Service Available

Your permanent magnet problem will receive the same experienced consideration from Crucible's unsurpassed staff of metallurgists and production specialists. Please give full details. Crucible Steel Company of America, General Sales Offices, Oliver Building, Pittsburgh, Pa.

CRUCIBLE first name in special purpose steels

52 years of Fine steelmaking

Midland Works, Midland, Pa. • Spaulding Works, Harrison, N. J. • Park Works, Pittsburgh, Pa. • Spring Works, Pittsburgh, Pa. National Drawn Works, East Liverpool, Ohio • Sanderson-Halcomb Works, Syracuse, N. Y. • Trent Tube Company, East Troy, Wisconsin

briefing the news

High-Speed Computer . . .

Whirlwind I, an ultra-high-speed digital computing machine, is now in operation at the Massachusetts Institute of Technology.

One of the features of this fast electronic machine, the only large-scale computer of its kind in full operation in this country, is its electrostatic "memory," which exists in the form of specially designed electronic storage tubes.

With its ability to remember, act upon, and deliver information at a rate of 20,000 times a second, Whirlwind I is the first machine suitable for supplying instantaneous instructions for such applications as controlling aircraft traffic patterns. Whirlwind also has many other applications for the study of industrial process control, insurance handling, inventory, economic analysis, census problems, and scientific and engineering computations.

During the next year Whirlwind will be devoted to a variety of engineering, scientific, and industrial applications as well as to military projects sponsored by the Office of Naval Research and the United States Air Force.

Among the important studies to be made are problems of control where the machines, devices or systems to be controlled will operate at their own actual speeds. In such applications the computer receives a continuous flow of data to be processed instantaneously into instructions for operating the control system. For example, Whirlwind could be part of an air traffic control center, setting the flight pattern of hundreds of aircraft of varying types and speeds approaching the airport from several directions and leaving it for various destinations.

Whirlwind has fulfilled the principal objectives of the project, which were to achieve ultra-high speeds with a digital computer, high reliability in large electronic systems, and the application of a digital computer to control systems in civilian and military operations in terms of actual time and speed requirements.

During its tests Whirlwind was used to explore the optimum assignment of the proposed ultra-high frequency television channels to the various cities of the nation. It has also been used to produce the instructions for automatic control of large machine tools.

A long-range problem already being studied is the most efficient and economical techniques for pumping oil from subterranean reservoirs, a problem of vital importance to the petroleum industry in which an economy of one per cent in production may amount to millions of dollars.

Whirlwind is an electronic digital computer. Once a problem has been inserted, the machine operates automatically. High-frequency electrical pulses travel along transmission lines from one element of the computer to another, causing electronic circuits to be turned on and off. The resulting electronic states of these circuits represent the numbers in the problem. Since Whirlwind selects, remembers and operates on all the digits of the number simultaneously, it can complete many thousand arithmetic operations per second. It can solve in fifteen minutes some problems which would require years of work by manual methods.

Every computing system has certain basic elements. In a typical manual system these elements might be the familiar desk calculator, an operator, a notebook for entering incoming data and recoding results, and messengers to bring in the problem and carry away the answers. In Whirlwind I, the arithmetic element corresponds to the desk calculator, the control may be likened to the operator, the storage or memory is the notebook, and the input and output are messengers.

Of particular interest electronically is Whirlwind's internal memory section. By means of specially designed electrostatic storage tubes, a sixteen-digit number can be read into or out of the machine's memory in twenty-five-millionths of a second. Each electrostatic storage tube, like a television tube, uses a movable electron beam to distribute information over a surface. A high-velocity and sharply focussed electron beam "writes" a digit in the form of a charged spot on the storage surface. The same beam is also used to "read" the stored information. Still another guardian beam keeps digits "in storage" for as long a period as desired.

Crystalline Plastics! . . .

Heat treatment of plastics to give them desired properties, using methods similar to those now employed with metals, is foreseen by a General Electric chemist. He described how plastic crystals may be made to form by proper application of heat in a manner closely analogous to crystal formation in a metal such as steel. In the plastic, as in the metal, each crystal forms around a nucleus of some foreign matter, or "dirt."

His research was concerned with a plastic bearing the chemical name of "polychlorotrifluoroethylene." As prepared, it is in the form of clear sheets. If heated to more than about 400° F., at which it softens and becomes rubbery, and then allowed to cool slowly, the sheet becomes cloudy.

Studies of this cloudy plastic by special microscopes, X-rays and other methods, reveal many tiny circular groups of crystals, each group a hundredth of an inch or less in diameter. The electrical and mechanical properties of the plastic containing crystals are very different from those of the normal form, where there is no regular order in the arrangement of the atoms of which it is made. In a crystalline material they are arranged in a regular lattice. The crystal formation occurs mainly at temperatures above 350° F. The nuclei, around which the crystals form, are provided by the "filler" that is added to the plastic in manufacturing.

Similar effects occur with many types of plastics including nylon and polyethylene, which is widely used as a transparent covering. In discussing possible applications of his work, the G.E. scientist said that choice of the proper heat treatment and filler might afford means of regulating the properties of a plastic.

For example, he added, if a plastic of considerable tensile strength is desired, many crystals might be formed. If, on the other hand, it was desired to have one that could be flexed back and forth a great number of times, without as great resistance to being pulled apart, the non-crystalline form might be preferred.

Similar methods are widely used in the heat treatment of metals, he pointed out. They may be heated, then cooled, and held for a certain time at a lower temperature. This induces formation of crystals of the size and distribution needed to give the qualities that are required.

What decides wages?

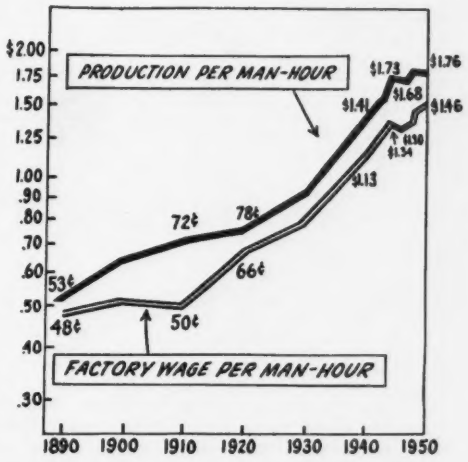
What you and I produce

THERE IS ONE RULE OF NATURE that all the governments, laws, unions and contracts cannot change: a man can be paid *only* out of what he produces, and the more he produces the more he can earn.

AND, that line "Factory wage per man-hour," shown in the chart at right, has gone up and up only as American business has put better and better *machines* to team up with American workers. *Machines* help the worker produce more and so earn more.

And *machines* can come only from the savings of investors—the savings made out of investor profits.

So—profits plus machines plus workers who use them well, equal constantly rising savings and standard of living. Whoever attacks *profits* is attacking *you,* and your family. Never forget it.



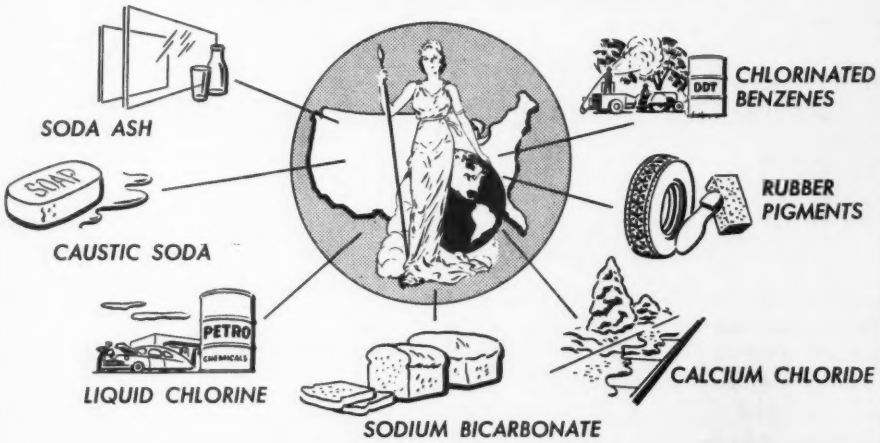
Production per man-hour represents the total national income produced per man-hour worked by all employed persons. Factory wage represents average hourly earnings of factory workers. All figures are in dollars of 1950 buying power to eliminate price changes, and show real purchasing power.

Source: Labor's Monthly Survey, American Federation of Labor.

WARNER & SWASEY
Cleveland
Machine Tools
Textile
Machinery

YOU CAN MACHINE IT BETTER, FASTER, FOR LESS WITH WARNER & SWASEY TURRET LATHES, AUTOMATICS AND TAPPING MACHINES

Columbia-Southern



Serves The Nation

Take a look. Touch something. In countless products you see or touch, Columbia-Southern chemicals play an important part.

Throughout industry, Columbia-Southern chemicals are used for such diversified purposes as pickling metal, processing textiles, manufacturing glass and soap, chlorinating water, compounding rubber and plastics, making insecticides, drugs and baking blends to mention only a very, very few.

Columbia-Southern is constantly striving to find new uses for its products, to improve present uses, and to effect economies wherever possible in manufacturing and delivery for the benefit of everyone.

Columbia-Southern Chemical Corporation . . . a leading producer of alkalies and related chemicals for more than a half century . . . is a subsidiary of the PITTSBURGH PLATE GLASS COMPANY.

College Faculty Members: While diminishing enrollment in Chemical Engineering promises greater opportunity to the student, it leads in turn to a potentially critical manpower shortage of trained chemical technicians.

We urge you to seek the support of community, church, school and social leaders in directing the career study of high school and preparatory students toward the opportunities in Chemical Engineering.

COLUMBIA-SOUTHERN CHEMICAL CORPORATION

SUBSIDIARY OF PITTSBURGH PLATE GLASS COMPANY

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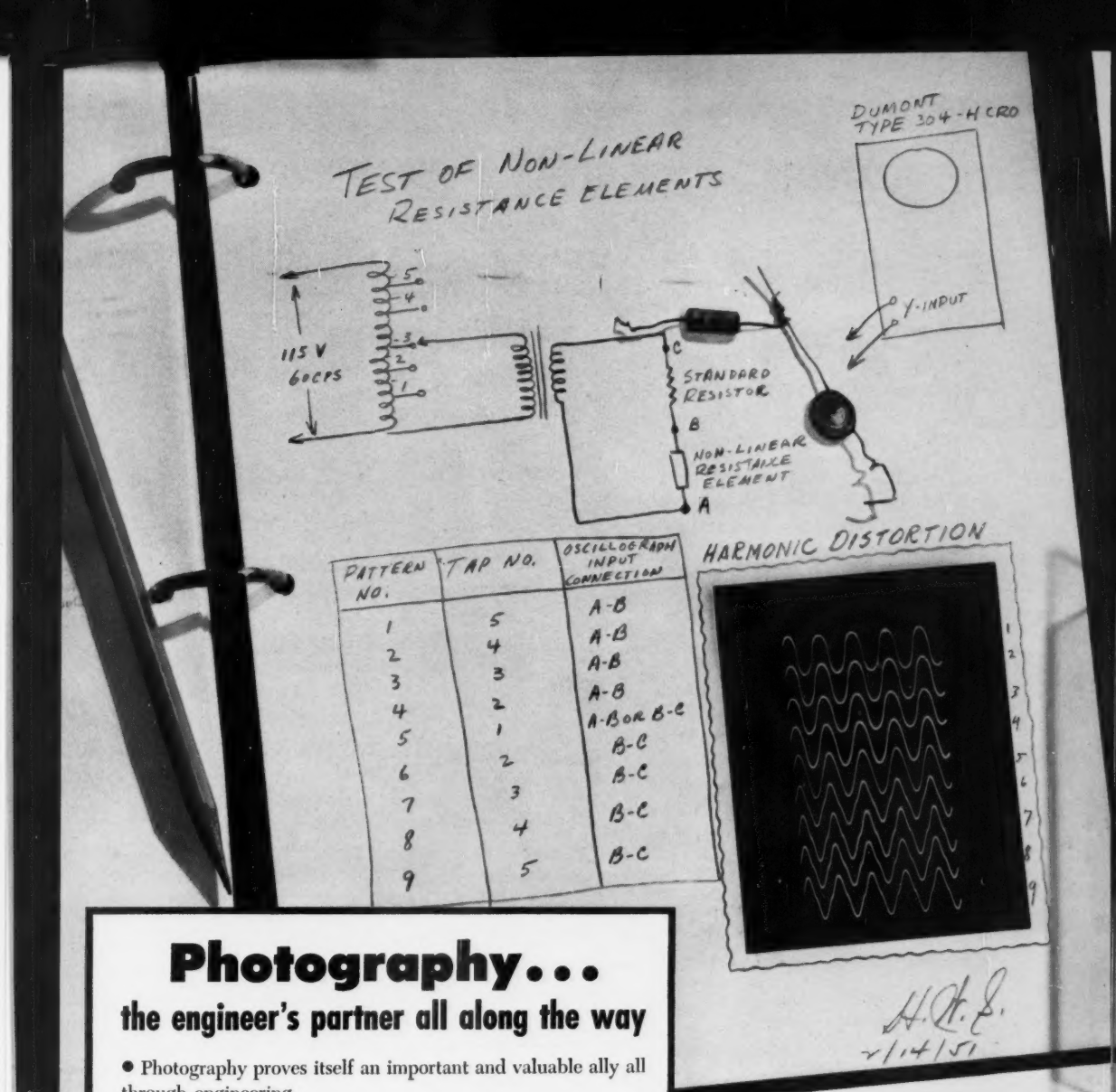

Photography...

the engineer's partner all along the way

• Photography proves itself an important and valuable ally all through engineering.

Its speed in copying and reproducing data saves valuable time. Its use in radiography and instrument recording improves manufacturing processes and finished products. High speed movies help solve design problems.

Applications of photography in science and industry are steadily multiplying. This has attracted graduates in the physical sciences and engineering to find positions with the Eastman Kodak Company. If you are interested, consult your placement office about arranging an interview with an Eastman representative, or write direct to Business and Technical Personnel Department, Eastman Kodak Company, Rochester 4, N. Y.

FUNCTIONAL PHOTOGRAPHY

serves industrial, commercial, and scientific progress

Here photographic oscillograph traces become an indisputable part of an engineer's notes, recording the effect of a new electronic circuit element on wave form. This record of performance stands ready for new evaluation at any time.

Kodak
TRADE-MARK

We conducted a poll* of '41 graduates to find out:

HOW HAVE THEY MADE OUT IN 10 YEARS WITH GENERAL ELECTRIC?

Here are the results:

1. TRAINING. On the average, college graduates who came with General Electric in 1941 have taken between three and four Company-run training courses. Some have taken as many as seven. These have included courses in business management and accounting, in sales, manufacturing, and in many phases of engineering. Graduates report that this training has been a big help in furthering their careers. As one expressed it: "These courses are essential to certain fields of endeavor—so essential I am still signing up for additional courses."

Other comments: "These programs are not the purely academic ones of school days. They are practical, interesting, enable one to do a better job and enjoy it more." "The G-E Sales Training Program was definitely instrumental in helping me find my present position." The training programs have been a very essential link between my college training and my present work." "I wish I could have known then how valuable these courses were going to be later." "They confirmed my original opinion that G.E. offered the best training for engineers."

2. EXPERIENCE. These graduates have had an average of three different rotating assignments in various phases of the Company's work. A typical example included assignments in radio test, in motors and generators, and in the industrial control development laboratory. Graduates express three main benefits derived from the G-E rotational job programs:

a. They provided opportunities for deciding on a definite field of interest. Typical comment: "I didn't know what kind of work I wanted to do. Rotating assignments helped me make up my mind."

b. They complemented college training with practical experience. "They helped me realize methods of manufacture and testing of different apparatus."

c. They provided valuable associations and contacts. "Changing jobs five times brought me a variety of friends and contacts I'm still grateful for."

3. PROGRESS AND ADVANCEMENT. 88 per cent reported that they felt their progress in General Electric has been satisfactory. Nine per cent described their progress as "average, so-so," with three per cent reporting "unsatisfactory."

Comments: "It's been no Horatio Alger success story, but I feel pretty good about it." "If next 10 years have the same trend, will be very happy." "Satisfactory and entirely fair." "I don't know anyone on the outside who has done any better in the same time." "Satisfactory. I've been a G-E salesman, field engineer, and am now group leader in a G-E design engineering department." "I have felt like a kid in a candy story owned by his father. There are lots of choices and his only problem is to pick out what he likes best."

**Facts and statements in this advertisement were compiled from a questionnaire submitted to '41 graduates still with General Electric. Participants returned questionnaires unsigned, enabling them to be full and frank in their answers.*

You can put your confidence in—

GENERAL ELECTRIC